4/b (cont)

models which can be perturbed to evaluate the net and make
recommendations or implement improvements to the software.

4. Establish a support function, perhaps independent of the soft-
ware developer, to establish and document the protocols.

22

4)   (cont)

c)   Configuration Control

The configuration control effort has been handled in a rather in-
formal fashion with a great deal of autonomy and an indefinite di-
vision of responsibilities among the organizations that address the
various elements of this function. Personal contacts, telephone
conversations, and understandings are relied upon for day to day
operation.

This environment is a natural outcome of the progressive R&D atmosphere
that was necessary for the development and implementation of the
network concept. It was appropriately adjudged that too much control
would have lengthened the time frame of progress. The system is
still relatively new and in a constant state of flux but the
essential task of setting up an interactive resource sharing net-
work has been accomplished. As the ARPANET moves more and more
toward becoming an operational utility all of the management
activities need to be formalized and the policies and procedures
made definite.

The network does not really exist as an entity now but rather as a
group of cooperative but essentially autonomous computer systems.
There is a whole set of activities which can't proceed until it
evolves into such a total system. The sophisticated utilization
of multiple computers for a single application depends upon having
the individual services at a sufficiently reliable and accessible
level. This in turn cannot be effected without direction, accurate
documentation and active exercise of control.

RECOMMENDATIONS

Current practices have led to a scarcity of accurate documentation.
The NIC directed effort has not been sufficient due to its passive
nature. Responses to questionnaires and voluntary submittal of in-
formation have been sparse. A more active documentation effort
should be undertaken. Host sites may not have the time or sufficient
interest or manpower to generate complete documentation and a
separate organization to aid them in this function is required.
Current methods are too informal and inefficient from an operations
standpoint.

Consideration should be given to directing the network analysis
effort and coordinating the various organizations involved. No
quantitative use is currently made of the data taken by BBN or the
NMC. The NAC studies are completely divorced from operational con-
siderations and no effort has been made to verify the assumptions

4/c   (cont)

made in their analyses. With the NAC software available on-line,
as is projected, an evaluation and integration of the various
analytic efforts directed toward characterizing system performance
seems a natural and advantageous undertaking.

As the network expands it will become necessary to evaluate more
closely the roles of both servers and users, and their inter-
relationships. A healthy mix of resources and customers must be
maintained in order to insure high utilization levels and sufficient
processing capacity.

4)   (cont)

   d) Network Equipment and Communication Channels Reliability,
       Availability and Capacity

As the network grows and achieves a greater operational identity the
need for a systems effectiveness effort will become more pronounced.
The existance of the elements and considerations necessary to es-
tablish system effectiveness are available however, there does not
appear to be any coordinated effort towards this end at the present
time.

The advertised error rate of the network is 1 in 10^{12} or approximately
one undetected bit error per year. Such a small probabilistic fac-
tor cannot be realistically measured nor would there be any reason
for it if there is confidence in the design implementation. The
number of retransmissions that occur, however, is noted by the NCC
and this data should be reviewed and analyzed constantly and closely
in order to identify and correct recurring and hidden causes for
retransmission.

The current reliability of the IMP/TIP hardware is 98% and is not
acceptable primarily, because there is no redundancy in this area
and when its IMP/TIP is down the Host is down and connectivity is
impaired. The desired reliability figure is 99.9%. To attain that
may require redundant hardware, however prior to this costly under-
taking it is highly advisable that an in depth analysis of the
failures be completed to identify and if possible correct the actual
causes of failures. Some of the necessary information is already
available at the NCC but is more qualitative than definitive in
this regard. Another area to be addressed is the non-availability
categories of the IMPs/TIPs. In this respect possibly the only
changes necessary to improve reliability would be in procedures.
The operating structure of the network and status reporting system
lends itself readily to complete automation of determining, storing
and presenting the referenced reliability parameters, given adequate
off-line storage mediums. Some minimal programming at NCC would be
required to categorize and store the run data for processing and
presentation of reports.

The capacity of the network under varying conditions is based on
an average rate model, and requires certain general assumptions.
NAC does not use any data from BBN or the NMC to verify or modify
their analysis. NMC does perform measurements of network operation,
but little has been done to characterize system performance. NMC
realizes that their studies have not given sufficient attention to
the perturbations caused by the measurements, or to the base level
of overhead traffic. NMC has been hampered by an inability to
generate high traffic levels, and would like to encourage high rate

4/d (cont)

Host traffic generators for measurement use. Systems capacity has
not been measured due to these difficulties, however, except in
special circumstances 50 kilobit per second circuits are used. The
network overhead reduces this to effectively 45 kilobits. Data
should be gathered to determine the effect packet retransmission
has on this figure.

NMC has made observations of real traffic moving from IMP to adjacent
IMP, and has concluded that long multipacket messages show much
better throughput for destinations many IMP hops away from their
sources. Buffer allocation presently limits message length to
eight packets. This maximum message size, packet size of approximately
1,000 bits were established somewhat empirically. Analysis effort
is indicated to optimize packet considerations as data on network
usage becomes available.

Capacity presently assumes high peak to average traffic with the
goal of interactive usage requiring an end-to-end delay of less than
½ second. This leads to line capacities greater than that necessary
to support the average traffic of all the sites. As network utiliza-
tion increases, at some point, capacity must also increase. Whether
some denigration of service should be sustained, for reasons of
economy, is yet to be determined. Current traffic is well below
capacity, and costs have only been estimated, so this question
has not been addressed.

Network studies have been conducted by several organizations and
individuals predominantly on a theoretical level. NAC has de-
veloped a rate model of the network. UCLA and BBN have simulation
models. Graduate students at UCLA are working on analytic methods
of generating network topologies. The NMC has done studies on
point to point throughput, some cost relationships, and on buffer
management.

Much good work has been done but in a widely scattered and diverse
manner. The various efforts should be coordinated and directed
toward the common goal of characterizing the network as an entity.
Much more verification of analytic techniques should be done through
measurements on the network. The need for a coordinated, overall
systems analysis effort will become increasingly apparent as the
network emerges from the R&D phase.

RECOMMENDATIONS

It is recommended that a single agency be given the responsibility
of establishing and implementing a total systems approach to the
network. This effort should include establishment of an overall

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4/d   (cont)

plan, identifying the participating agencies, level of effort re-
quired, goals to be attained, and trial time schedules. Actual
time schedules would have to be established by the individual
agencies involved, and once established would serve as a motivational
tool, rather than a forcing device.

The implementation of such an effort will require the ability to
cross administrative, political, and corporate lines in a manner
that will promote the cooperation and coordination necessary to
the success of a total systems effort.

4)   (cont)

    e)   Network Configuration Analysis

A significant amount of valuable software has been developed by NAC for network configuration analysis of the ARPA net.   This software has been refined to a point where it is quite effective.   It has the capability of optimizing for both throughput and reliability versus cost.   However, very little use of it has been made for optimizing reliability.   The model in use is static, rather than a dynamic model, and does not make use of real data gathered on the network in determining topology.   Neither has there been any efforts to validate the current model using actual data.

RECOMMENDATIONS

A central organization should be assigned the responsibility for accomplishing, at least the following tasks:

1.   Gathering and inclusion of reliability data into the topological analysis.

2.   Collect and use real network data, to the greatest extent possible, in determining network configuration.

3.   Validate the topological models using data collected from the network.

4)   (cont)

f)   Requirements for Special Technical Assistance

The "Request for Comment" is the most widely used document for
identifying problem areas requiring special effort. These would be
directed to ARPA or BBN as may be appropriate. The Network Working
Group, while not very active at this time, does serve as a means of
identifying Host to Host protocol problem areas.

Network facilitators are able to provide some assistance on special
interface requirements, and refer the new member to a more knowledge-
able Host if possible. BBN may also be contacted in this regard. The
new member can obtain some knowledge of network and Host level pro-
tocols from the existing documentation. For special requirements or
specific questions the customer is encouraged to contact other users
as may be appropriate. Training assistance as such is not available.
There is no effort to provide in depth services to a new user during
his entry to the network. No consulting service, or other single source
capable of providing complete network entry and initial operating in-
struction has been found.

The network measurement center at UCLA presently performs extensive
statistics and trace gathering in connection with regular message
flow and artifical traffic generation. Repeatability of these tests
is questionable due to the problems associated with performing con-
trolled tests within a continuously used and variable dimension oper-
ating system.

Statistical analysis and/or simulations are required to evaluate the
routing algorithms, buffering technique, traffic distributions and
other system parameters. Further assistance is required to develop
a procedure which can be used for a higher level of IMP/TIP software
verification.

Optimization effort is limited at this time to the NAC topology
endeavor. Optimization effort on the communications level is of
prime importance in increasing cost effectiveness, and "fine tuning"
of the network. Factors such as message lengths, packet size, and
Host to Host protocol actualization, greatly affect system operation
and could benefit from optimization studies. Optimum usage of the
network has not been defined. A periodic report of various transfer
rates etc., and how they were achieved would be desirable as a guide
to the new user, and to stimulate activity toward a "most optimum"
network usage.

4)   (cont)

    g)   Prospective Customer Briefing Requirements

The prospective network member is briefed in a rather informal manner. During the initial briefing at ARPA he is briefed on the network in general and on the one time and yearly recurring costs, is advised of other sources of information such as BBN, MITRE, NIC, etc. He is then directed to one of the network facilitators for further indoctrination and assistance in procuring the necessary Host services and the required software. Commitments and obligations of the prospective customer are determined by ARPA, and other than general obligations for provisions of access, accountability, etc., no formal commitments are sought from the prospective member. Presently the new member must do a fair amount of investigation to determine hardware interface, costs, and availability. The methods for briefing the new customer are rather informal and consists of limited use of blackboards, drawings and some reference material. In general it takes much too long and involves many meetings with the facilitators and others to become an active network user.

RECOMMENDATIONS

A single organization should be tasked with the responsibility of assisting a new user to become an active network member. Formal briefings should be prepared that are all inclusive and directed to both the technical and executive levels of the new member organizations. Up to date and uncomplicated material should be prepared to expedite the new members proficiency in using the network. Hand holding should be a continuing thing for a period of up to two weeks with the new user at his facility. Following this period, active follow up action on the part of the hand holding group should be a periodic requirement until the new user is proficient in use of the network.

4)   (cont)

   h)   Advanced Planning Recommendations

ARPA presently does all planning of future developmental effort.
BBN is tasked for the actual development of the hardware. This
arrangement, judging from results, is more than adequate. As more
reliance is placed on the network, new developments must be in-
corporated into the network in a manner causing the least inter-
ruption to satisfactory service.

Priorities for developmental tasks are established by ARPA in such
a manner as to provide an orderly time sequence of events.

Statistics on the growth in traffic volume, and the number and
types of users could be obtained. A statistics gathering and re-
porting method permitting growth projections, and categorization
of users, has not been established. The "healthy net" concept
should be more clearly defined.

Systems level planning is accomplished in a manner that provides
for technological advances. The HSMIMP is cited as an example.

The impact of new development is assessed in terms of higher
traffic volume, and cost effectiveness. The dual logistics, pro-
gramming, software promulgation, and other operational aspects
must be evaluated before a true impact can be determined.

A considerable amount of data is gathered by BBN and NMC. However,
this data is not made available in a form readily usable to establish
present or projected requirements.

Due to the R&D nature of the on going development, cost effectiveness
is evaluated in conjunction with what is determined to be the best
technical approach. Cost effectiveness will increase in importance
as modifications are made to the network. A cost analysis pro-
cedure should be implemented as an aid in evaluating future de-
velopment.

The implementation of the network will be established by ARPA
requirements. There are indications that a more detailed implementa-
tion plan would provide better coordination between the agencies
involved. In the case of the HSMIMP an implementation plan
identifying all action agencies, and a detailed test plan to de-
termine capability and operational readiness prior to network
commitment appears highly desirable.

4/h   (cont)

RECOMMENDATIONS

It is recommended that a single agency be assigned the responsibility
of gathering and assembling cost and operational statistics necessary
for an advanced planning effort, and to perform an implementation
planning function that will provide fully detailed plans, with
action agencies assigned, and to coordinate the implementation of
these plans. This type of planning and assignment of responsibilities
should insure the least possible interruption of network services.

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5)   Network Operations Requirements Study

   a)   Inter-Company Coordination Arrangements.

The inter-company coordination arrangements maintained by ARPA in its
contractor contacts has been rather informal and conducted in a "can
do" atmosphere. This has resulted in remarkable accomplishments in
creating and expanding the ARPANET to its present form. It has been
ARPA policy to find a reliable, conscientious group; contract with
that group to perform a particular job and then with a minimum of
direction permit them to accomplish the work. This attitude has
permeated the coordination arrangements of their contractors and
subcontractors.

The BBN negotiations with Honeywell resulted in delegating the main-
tenance responsibility completely to Honeywell. This has included
responsibility for the spare parts, installation effort, and even
some of the retrofits. In nearly all instances the maintenance
effort provided by this arrangement has been satisfactory.

There has been very little planning or scheduling of contractor support
activity other than the BBN-Honeywell scheduling of preventive main-
tenance. The measurements conducted by NMC are in most cases not
coordinated with the rest of the network.

The network has evolved in a cooperative atmosphere and most requests
for network support are satisfied in this way.

Initial contacts with AT&T for new installations are informal with
the result that lead times are held to a minimum. An easy informal
relationship has developed between BBN and AT&T so that the check-
out and maintenance is accomplished with a minimum of network dis-
ruption. It has resulted in a great deal of benefit to the carriers
in their quality and reliability efforts on wide band facilities.

The character of the ARPANET is changing almost as fast as it is
expanding. More and more voices are heard asking for help in the
costing and accounting area, guidance to system programmers to keep
them from burdening other hosts in the net with trivia, guidance on
goals, help in acquiring resource documentation and many other aspects
of the network.

RECOMMENDATIONS

A beginning must be made to formalize somewhat the inter-company
coordination arrangements. Within the BBN-Honeywell maintenance re-
lationship a formal requirement for reports of corrective maintenance
is needed; formal scheduling of retrofit installations would ensure

that all machines are retorfitted at about the same time; a more
formal logistics control is desirable. The measurements conducted
by NMC should be formally scheduled through the operational control
center of the net, particularly if there is a possibility of the
measurement disturbing network operation.

The need within the network community for an established single point
of contact which is able to appropriately respond to requests for
support or service is rapidly accelerating and may be critical in the
near future.

The formal requirement to provide up-to-the-minute information to
NIC to maintain the network directory should be levied on every Host
organization.

nately this has not been fully the case in the procurement of services for the network, but this is not surprising in view of the rapid network expansion.

Complete retention of procurement authority by ARPA has somewhat inhibited application of cost and reliability effectiveness criteria particularly in software and service areas.

RECOMMENDATIONS

The establishment of published policies for the procurement of documentation of resources and network services is considered essential for continuing stable network expansion.

It would be highly desirable to have cost analysis and reliability analysis studies performed to provide criteria for procurement decisions. The data for these recommended studies should be embodied in the modules of the proposed Automated Management Information System (AMIS).

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5/d   (cont)

The need for a thorough cost analysis study of all facets of the
ARPANET operation is imperative.

No formal definitive cost analysis effort or cost accounting system
was uncovered during the study. This is not surprising in the course
of a development where the major emphasis is on technological ad-
vances and getting the network to operate as it was intended. But
now that the network is assuming a more operational character in-
volving servers, users, and interactive research centers, an
organized definitive cost analysis and cost accounting organization
must be instituted to properly address and identify all the cost
factors involved and the possible tradeoffs that must be considered
in an operational environment.

5) (cont)

    e) Reporting Requirements

All ARPA contracts require the periodic submission of management/
administrative reports and technical status/progress reports. These
reports are of a narrative type, some of which are automated in the
sense of being filed on-line on a computer rather than in a hard
copy format. The Quarterly Technical Reports issued by BBN are one
example of the required reports. The BBN-NCC Monthly Statistical
Summary reports are not formally required, but have developed as a
result of ARPA-BBN interaction and as a by-product of monitoring of
the network by the NCC.

There are no requirements for reporting operational status, main-
tenance or logistic activities, reliability, quality nor cost
statistics.

RECOMMENDATIONS

Requirements to provide reports can only be justified by the needs of
management for the tool the report provides. It is recommended that
an automated management information system (AMIS) be developed and
implemented to provide the report tools needed by management for
planning the development of the network.

A logical approach to the AMIS design is that of building block
modules, in which the first modules to be developed and implemented
are those that collect and store data which is currently available
within the network. One of the most crucial modules for the utility
of the AMIS is the report output module. This should be a query
responsive program which can address and retrieve data from one or
several of the modular data banks, and compare, summarize, or operate
on the data in response to the original query. It should have the
capability to accept a query for a report tool that is needed on a
periodic basis, and store the query so that the response is auto-
matic output with the periodicity requested. Another feature of this
module should provide for the security that is deemed necessary by
management. This security feature would allow upper management to
access all of the data bank modules with no restriction on their
queries, but the quality control analyst would be restricted in queries
he could pose to the AMIS. Wide latitude should be provided in the
output formats which may be elicited by the query.

The module which addresses data necessary for cost analysis should
embody a complete mechanism for automatic cost accounting and billing
for network use, even though it is inactive at this stage of ARPANET
development.

5/e   (cont)

The data collected by the NMC in the course of their studies should be addressed as a module of the AMIS. The data collected by MIT on the availability of hosts on the network should form another module of the AMIS.

The complete range of management tools provided by reports on maintenance, logistics, quality, reliability and costs should be thoroughly examined and where necessary, provide a module and the capability to collect the required data and make it available to appropriate users.

The dynamic expansion of the ARPANET should be a prime consideration in the design criteria for the development of all the AMIS modules.

f)   Inter-Agency Coordination

The coordination between DECCO and ARPA for the acquisition of wide
band facilities has been adequate for a tremendous network growth.
This is not so true for the NMC and NIC efforts. It is quite possible
that a more aggressive attitude to what was desired from the NMC would
have produced a continuing coherent system of network measurements
for network understanding rather than isolated reports. A more
specific policy on the obligations of network members as to supplying
documentation of their resources and points of contact within their
organization would undoubtedly have enabled the NIC to do a much more
creditable job with their assigned task.

There is a need for more specific policy in the area of responsibility
of network agencies to avoid duplication of effort. An example of
this is in the NMC responsibility, where BBN doesn't consult with
NMC but simply makes their own system measurements for their under-
standing of the network and its interaction with the IMPSYS software.
While this has been practical during the embryonic stage of ARPANET
development, it is clearly apparent that it will result in excessive
overhead traffic which will be unbearable as the net matures. This
is true of the measurements made by other Hosts such as MIT and of
the excessive use of the ECHO protocol by certain systems. All of the
use of these measurement schemes should be controlled and policy
should dictate that a controlling agency for measurement be established.

Specific statements on the obligations of each network member with
regard to the documentation of resources and updates thereto, and to
supplying directory information would allow the NIC to provide much
more useful functional documentation. It is also suggested that a
customer service be instituted to aid the network member in pro-
viding this documentation in the format for inclusion in the NIC
functional documents.

RECOMMENDATIONS

It is recommended that a single organization be responsible for
actively documenting existing and future nodes and for providing this
documentation to the NIC for inclusion in the functional documents.
The full cooperation of each node is essential to this effort. In
addition this organization should be responsible for assisting new
customers in the use of the functional documents and of the ARPANET
to realize the full potential of the nets capabilities.

In the area of network measurements it is recommended that a single
point control agency be established to coordinate and control all

5)   (cont)

   g)   System Expansion

There has been no effort by ARPA to solicit prospective network
users, but their procedures for the investigation, approval, and
integration of new users have been quite adequate for tremendous
expansion that has occurred since 1969.

The only effort to determine the network self-sufficiency threshold
was a study for Educom by the Wharton School of Business, however
their report was not available.

ARPA's goal is to put out an RFP within the next 18 months to get
someone to run the subnetwork commercially as a carrier. Technically
the ARPANET is nearing a threshold where resources and services are
available, reliable and accessible to the extent that a person can
reasonably come in, choose his tools and swing them around to do
his will. But from a management point of view much remains to be
done to reach a comparable threshold.

There are no indications that network management will in any way
restrict network expansion. The economic factors which limit ex-
pansion are the paucity of wide band facilities and the long lead
time to acquire them. If network expansion reaches an undetermined
point at which it is necessary to use some kind of an area code
routing scheme, the expansion would be halted for want of some very
high speed exotic hardware. If the HSMIMP development has been
completed, it may very well be the hardware needed to handle the
central point switching function.

Plans are well along for extension of the network via satellite
beyond the continental limits, but expansion by interconnection
with other networks such as MERIT or TSS will not take place.

Plans for higher bandwidth communication channels and message
processors with higher throughput are well underway with a HSMIMP
development program at BBN and an experimental 230 kbps link in use
at Ames.

RECOMMENDATIONS

The planning efforts by ARPA have admirably provided for the future
system expansion and we have no recommended changes.

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5)   (cont)

    h)   Policy As To New Customers

The sole arbiter over prospective members is ARPA and the criteria for
that decision, but not necessarily in order of importance, are first
a comparison of the network cost with their alternatives, second the
propriety of their membership in the ARPANET and last their use of
the net must in some way further the R&D goals of DOD and the network
development.

There is no formally established set of policies governing the new
customers obligations to the network nor the ARPANET guarantees to
the customer. The new user is required by the joining agreement to
treat the ARPANET hardware properly and allow access to that hardware
for maintenance purposes. A certain amount of pressure is exerted
by ARPA on all network users to conform to established protocols,
and on service Hosts to maintain reliable and efficient service and
provide an administration as convenient for the user as possible,
however none of this is guaranteed. The new member is obligated to
provide his own special Host/IMP interface and NCP software. The
ARPANET offers continuous communication service on the net but makes
no guarantee to that effect.

No effort is made to solicit new members for the ARPANET at this time.

RECOMMENDATIONS

The network development toward a more operational configuration dictates
the need for a more formal set of policy statements for the guidance
of new customers. These policy statements should address separately
the obligations of the three classes of new customers. The user class
is probably the simplest with their obligation limited to proper care
of and access to the network hardware, the server class should have
these same obligations, plus the requirements to supply complete user
oriented documentation on the resources offered and to provide some
consulting service to the user and to provide current directory in-
formation. One further obligation should be that once a resource is
offered to network users, it may not be withdrawn from service until
network management approves the action. The obligations of the inter-
active research centers would be much the same as user nodes plus the
obligation to explore with network management the usefulness of special
resources developed in their research efforts and when requested make
a resource available to the network users on their own or some other
machine.

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5)   (cont)

    i)   Equipment Control/Inventory Techniques

BBN maintains property control records of all major units of network
hardware and their location, and an annual inventory is conducted
with a report thru ACO channels. These property control records are
not automated and it would not presently be feasible to attempt an
automated equipment/configuration control system using this data
base.

BBN uses government property control forms to maintain their records
and they also maintain a file of signed receipts which acknowledge
delivery of network hardware at the installation site.

BBNs accountability system includes major hardware units but the
system does not attempt to account for parts or expendable items.
The BBN property custodian is responsible for all network hardware,
and he assures that each major unit has a government property tag
affixed and that it is entered in his property control record.

RECOMMENDATIONS

It is recommended that an automated equipment/inventory control
system be implemented as soon as possible. This activity is so
intimately a part of the complete cost analysis and cost account-
ability as to be a necessary adjunct to it. The system should
address accountability for parts and controlled expendables.

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3)   (cont)

    g)   Network Status Reporting

The network contractor has developed admirable statistics gathering
routines and a very thorough status and statistics reporting mech-
anism within the IMP operating program. The periodically reported
status and statistics data is used at the Network Control Center for
monitoring the health of the communications subnetwork as well as
for providing summarized reports to ARPA covering Host traffic
statistics and network availability figures. The reported data
and other statistical data gathered by the IMP program are further
applied to technical analysis for evaluating the effectiveness of
the IMPSYS algorithms as well as measuring parameters to foster
insight into the character of distributed networks. The only
criticism of this area might be that the analysis effort is usually
conducted only in response to identified problems as opposed to a
sustained analysis endeavor. In general the scope and quality of
the available statistics on the communications subnetwork leave
little to be desired but the use and application of the statistics
could be improved.

Statistics on Host responsiveness and availability are routinely
collected by the Network Measurements Center and other interested
Hosts. Little use is made of these statistics at present, but
they will eventually become an important user and management tool
in measuring server merit and capabilities. As yet little effort
has been directed toward further measurement of server characteristics
.in the form of resource availability statistics.

RECOMMENDATIONS

No changes are recommended to the present subnetwork status re-
porting techniques. It might be beneficial to direct more attention
to the statistics on Hosts' availability, and response over periodic
time frames, as the information looses its discrete identity
through summarizing.

3)   (cont)

   h)   Quality Control and Analysis

No requirement has been levied on the network contractor or any
other organization to maintain an overall quality analysis effort.
ARPA has generally retained the entire responsibility for evaluating
the quality of all effort involved in developing and operating the
network. This evaluation has been essentially restricted to
measuring accomplishments against goals due to the limited size of
ARPA resources and the lack of an organized management information
system.

No problems have been identified due to the present approach,
however it is readily apparent that more detailed analysis of the
network performance will become necessary as the network community
grows and changes in character. Cost and technical analysis of
the services provided to the customer will eventually dominate those
figures as they apply to optimizing the communications subnetwork.

RECOMMENDATIONS

An organized management information system should be established to
readily provide, in a presentable manner and timely medium, the
data required for analysis and decision making in the areas of cost,
technical, and reliability analysis. The management information
system should further provide on-line historical and scheduling
information relative to on-going tasks and advanced planning.

It is also recommended that resources be directed toward sustained
reliability and cost analysis programs that will aid and reinforce
the decisions that shape the character, purpose, and direction of
the network.

4)   (cont)

    a)   Hardware Development

Hardware development is accomplished by BBN as a result of require-
ments established by ARPA. The development to date consists of the
hardware and software for the IMP, and the TIP. On going work
covers the Satellite IMP and the HSMIMP (high speed modular IMP).

The Satellite IMP is being designed to work with satellite trans-
mission circuits, and is dictated primarily by the longer circuit
delays. Operation of these units with Hawaii, and Oslo is anticipated
during the first half of 1973.

The HSMIMP is being developed to provide a data throughput of 1.5
megacycles. This unit is being developed to handle traffic densities
anticipated when the ILLIAC IV at Ames becomes operational, and to
permit the network to be segmented by area. Operation of the
HSMIMP is anticipated late in 1973.

BBN also has responsibility for the Network Control Center. While
the NCC does gather operational data, it is not being used for
any extensive performance analysis type work.

RECOMMENDATIONS

In view of the goal of eventual transfer of the network to a
commercial organization it is recommended that an agency be assigned
the responsibility of gathering and assessing data as necessary for
a systems analysis effort. This effort should identify and define
the network parameters, identify the areas where optimization is
feasible, and the relative significance of each of these areas.

4)   Network Analysis, Development and Planning

      b)   Software Development

The software for the net has been as dynamic as the net itself which
is typical of a "state-of-the-art" research project. It has now
evolved into an operating system which is performing its defined
function. How well it is performing this function has not been
measured, in effect the very dynamics of the system have hampered
the measurement effort. To date, software simulations have not been
used as a tool for measurement and hence, revised or validated
system design. For example, the simulation of different routing,
queuing, and buffering algorithms, buffer sizes, traffic patterns,
traffic volume, etc., using data currently being collected by BBN
could be used as an effective system design and certification tool.

The checking out of software modifications prior to their implementa-
tion on the net has not been highly successful. A contributing
factor to this is the fact that the modifications must be checked
out on the BBN computer and whatever equipment happens to be in
transit to a new user. Another contributing factor is the lack of
documentation and certification of the software prior to its im-
plementation on the net. As more users come on the net and more
users become dependent on the net to get their job done, more con-
trol must be put on changes in the net to assure that the users can
rely on the net as a service.

The issues of Host protocols, and NCP development have been handled
by working groups and individual Hosts, which has led to the lag in
the development in this area. It would be advantageous to im-
plement a central point of control and support for this very
important task.

RECOMMENDATIONS

These recommendations are made, not as a criticism of how the net
has advanced to its current status, but rather with the realization
that the goal is to transform the net from its current R&D status
to a "commercially" viable service.

1.   Implement documentation and certification procedures for net-
      work software.

2.   Implement procedures, and capability to more thoroughly check-
      out software modifications.

3.   Establish a system analysis function, perhaps independent of
      the software developer, to develop statistical and simulation

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3/f   (cont)

RECOMMENDATIONS

It is recommended that an integrating force be initiated that could
establish and enforce clear (but not necessarily stringent) guide-
lines for the documentation, guarantees and procedures required in
locating and using resources available to the network community.

It is further recommended that a more extensive and aggressive
program of documentating network resources be undertaken to improve
the NIC role.

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3)   (cont)

    f)   Coordination Between Various Users and Communications
       Systems

Coordination of services required to maintain the communications
subnetwork is performed by BBN who also arbitrates any disputes
concerning these services. Disputes that cannot be resolved by
BBN are referenced to ARPA, whose decision is final.

There is no coordination and relatively few guidelines governing
interaction and transactions among members of the network community.
This approach has shortcomings which are expressed by a lack of
cooperation, coordination, and sense of direction among its diverse
membership. This can, in part, be attributed to the fact that the
network community is strongly oriented toward specific areas of
individual research and are only peripherally supportive of the
network as a communications entity. The dominating group in this
respect would be research dedicated sites that, though they may
have Hosts, they are not interested in marketing excess capacity
over the network (if indeed they have any). Network connection
affords them the advantages of communicating information and sharing
central files and processes within subgroups sharing mutual interests.

An ad hoc market place is established on the network by member
categories of servers and users. The service sites which provide
computer facilities for remote usage receive the benefit of using
the network as a means for marketing excess capacity. Complement-
ing the service sites are users, who for all intents and purposes
have no computing power at their local sites, but interconnect to
the network through a TIP in order to utilize the available services
connected to the network. Matching these members to achieve high
levels of utilization and concomitant operating economies is
hampered by the lack of a central brokerage agency to provide the
means by which interested users and service Hosts could be brought
together. The documentation (Resources Notebook) containing in-
formation on computing capacity available at each Host and the types
and cost of services provided, as well as the means of establishing
accounts and accessing the services is generally inadequate at
present.

This leads to agreements being made directly between the computing
centers and the users in an ad hoc fashion, with the user learning
of available resources through personal contact and associations.
This approach can tend to encourage use of local installations
(time sharing systems) which are easier to deal with (accounts,
guarantees, etc.) and find out about due to their proximity.

3)   (cont)

   e)   Software Certification

The software development practices of the network contractor is one
of the few areas where there is almost universal criticism expressed
by the network community. Although the network members recognize the
necessity for continued development and sympathize with the problems
presented with debugging a program of this complexity they become
uniformly upset when the network is inoperable for extended periods
of time while malfunctioning network software releases are being
debugged on-line by BBN. It cannot reasonably be expected that
major revisions to IMPSYS can be completely debugged prior to re-
lease into the network, but it should be expected that software re-
visions would be meticulously verified and reasonably checked out
to minimize errors prior to release into the operating system. The
problem can be expected to become even more acute due to the growing
size of the network community and the requirements for extensive
revisions to IMPSYS dictated by conceptual developments, expansion
beyond national boundaries, and adapting to advanced communications
mediums (i.e. broadcast satellites).

RECOMMENDATIONS

Resources should be directed toward establishing an effective
verification/certification program for IMPSYS development. The
effort should be directed toward reducing the deleterious impact of
revised IMPSYS releases on the operating network without imposing
unnecessary restrictions that would be nonconducive to responsive
and resourceful software development by the network contractor.

Clearly, one requirement would be to establish a test cell with the
capabilities to more closely approximate a distributed network en-
vironment with traffic simulation and other variable parameters that
would be established through network analysis. The modeling of the
test cell, once refined, will allow development of sophisticated
simulation and verification techniques that should yield a high
degree of confidence in revisions without ever imposing any re-
strictions on the developers of IMPSYS. Once the revision is
verified and released into the network there should be organized
simulations and measurements performed by, or in conjunction with,
the Network Measurements Center to further verify the new IMPSYS
version.

3)   (cont)

    d)   Hardware Installation and Modification

From an operations standpoint the date, location and configuration
of new node installations are of primary interest. Using this in-
formation the NCC can establish initial contacts and some famili-
arity with the applicable long lines controllers and Honeywell
field maintenance personnel concerned with servicing the new node.
Additionally they will prepare to insert IMPSYS revisions recognizing
the new node and Host(s), as well as updating their NCC monitoring
software and other NCC network monitoring peripheral tools (topology
displays, IMP configuration records, etc.).

As the installation date approaches they will review and adjust
scheduling of activity within the topology related to the new node
to minimize the deleterious effects of a prolonged outage during
the new node installation.

During the pre-installation period the NIC will establish the new
node within their distribution system by initially providing them
with the basic network functional documents and other appropriate
information. At the same time the NIC will begin to solicit,
assemble, and distribute information related to the new Host's
characteristics. Due to their passive role in soliciting infor-
mation the NIC may be unable to produce any information of value
on the new Host until well' after he is established on the network.

With respect to modifications, the control center schedules their
performance and must be cognizant of their application as it effects
diagnostics or the operating program within the individual IMPs.

RECOMMENDATIONS

The only recommendation in this area would be to raise the metabolism
of the information collection effort performed by the network in-
formation center as it is not sufficiently productive at this time.

3)   (cont)

c)   Planning and Scheduling

The planning and scheduling functions as pertains to operations, are performed by BBN in a reasonable and effective manner. The low level of utilization of network capacity during the development stage has deferred any stringent requirement for evaluating or analyzing the scheduling functions impact on capacity, response, etc. As traffic volume increases some form of systems analysis may be required to maintain an effective scheduling mechanism.

RECOMMENDATIONS

Consideration should be given to applying network measurements as an analytical tool to optimize the scheduling of element outages. In the same vein, a point will probably be reached whereby large scale network measurements, simulations, and modeling exercises by responsible or interested network researchers may have a deleterious effect on regular traffic throughput. Here again, a knowledge of network capacity would assist the network control center in scheduling tests of this nature so as not to affect the average user.

3/b (cont)

RECOMMENDATIONS

The establishment of a sustained maintenance analysis effort would
be beneficial with respect to cost effectiveness and, indirectly,
customer satisfaction. The program should be oriented toward de-
termining the levels and degree of maintenance required for a dis-
tributed network with a heterogeneous membership dispersed over a
broad geographic area. Additionally, an analysis program would
provide a means to measure the performance and effectiveness of the
contracted maintenance effort.

3)   (cont)

   b)   Maintenance (Hardware/Software)

BBN has the responsibility for maintaining IMP to IMP communications
service within the communications subnetwork. In performing this
function they have retained responsibility for the IMP operating
software and have contracted for IMP maintenance service from Honeywell
Corporation. They further ensure service by coordinating response
from the carrier, who has responsibility for modem to modem main-
tenance of the communications channels.

The degree of rapport between these groups with respect to restore
activity is exceptional with relatively none of the finger pointing
problems that are so common when independent elements are melded
into one function. It is generally recognized that this environment
is largely due to the proficiency of the network control center in
correctly diagnosing problems and producing relatively few false
alarms.

The effectiveness of the preventive maintenance effort is difficult
to measure as very little maintenance or reliability analysis takes
place under the existing contract. The reliability figures pro-
vided by BBN indicate the failure rate of the IMP to be nearly four
times as frequent as the rate Honeywell predicts for the basic 316
computer. It is possible that the large discrepancy between these
figures is due to the interpretation of what constitutes a failure,
however it does raise the question of whether some maintenance
analysis might not be desirable.

Although the network is of a continuous operational nature the present
Honeywell maintenance contract covers repair response during prime
time periods only, with additional cost for seldom requested "brown
time" effort. The extent that the two situations might be incom-
patible could not be measured during the study. However it is
reasonable to assume that prime time service in a continuous oper-
ations environment is not an optimum situation. The service node
that is partitioned from the network may not feel the effects of
the partitioning but his network users will. Further, an inoperable
IMP being held for prime time maintenance at an inactive location
is affecting overall network capacity and is a potential hazard to
partitioning his active neighbors in conjunction with other IMP
failures. In general, as the network encompasses an ever increasing
time zone spread the distinction between prime time and brown time
becomes meaningless to the members of a distributed network. The
researcher in Honolulu views prime time on his resource at MIT or
the University of London in a far different manner from the main-
tenance representative in Massachusetts or London.

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3)a (cont)

RECOMMENDATIONS

As the network community expands and traffic increases thru increased
participants and knowledge more attention should be devoted toward
increasing network availability by further improving the diagnostic
tools available to the NCC to insure prompt restore action on all
failures. Attention must also be directed toward ensuring that the
network control center is continuously capable of monitoring and
servicing all elements of the network regardless of the effects of
NCC equipment failures or partitioning of parts of the network. This
is becoming increasingly important due to the diversity of the communica
tions subnetwork operating elements (customized IMPs, HSMIMPs, etc.).
It is recognized that the NCC generally has adequate back-up monitoring
equipment available and it is further recommended that some form of
back-up monitoring and reloading routines be distributed at friendly
Hosts in a manner that would provide the NCC with the capability to
activate the routine and receive the necessary information for ser-
vicing parts of the network that might become inaccessible via the
network due to partitioning.

A formal scheduling system should be established at the NCC that would
ensure the entire network community is aware of the scheduled un-
availability of all nodes. On-line distribution and storage of the
schedule on a periodic update basis would be the preferable means of
ensuring all members are informed on a timely basis.

Although the problems associated with network user assistance can be
attributed to the growing pains associated with any original enter-
prise, the de facto market place established by the network must be
organized to some extent if it is to satisfy users and foster growth.
An integrating force should be established that is responsive to the
needs of the entire network community (servers, users, research) and
also will act as a forcing function in establishing and maintaining
the documentation and procedures required to bring servers and users
closer together.

3)   Network Operations Responsibility

   a)   Routine Operations

The responsibility for maintaining orderly network operations has
been assumed by BBN. In response to the need for monitoring network
operations during network development BBN established a network
control center at their Cambridge facility. This control center has
gradually evolved from "as available" coverage to continuous coverage
in the essential areas of scheduling and monitoring network operations.

The control center appears highly effective in the area of problem
identification, diagnosis and restore action. Contributing to this
effectiveness are very good working relationships with the main-
tenance contractors and utilization of a well designed status re-
porting and diagnostics system. On the other side of the ledger is
the presently unavoidable, but undesirable, practice of reducing
availability by deferral of restore activity on complex problems that
are held for analysis by BBN development personnel. One deficiency,
of consequence, is the absence of provisions for maintaining un-
impaired network control under partitioning circumstances. If any
part of the network is partitioned from communications with the net-
work control center, that part of the network must rely on individual
user recognition and reporting of any subnetwork problems.

The scheduling of activities (installations, maintenance, etc.)
affecting communications subnetwork capacity is executed with reason-
able logic and acceptable effectiveness. However, there are apparent
deficiencies in the coordination details with respect to the accord
and notification of all involved participants, including interested
parties. An example is that the entire network community is not
formally notified of when individual Hosts will be unavailable due
to scheduled subnetwork outages. This practice can be distressing
to the network user who is attempting to schedule his activity with
various Hosts.

The network user, new and established, is probably the most neglected
element within the present development atmosphere. The mechanisms
for assisting and encouraging new members are relatively informal or
nonexistent in comparison to the services offered by the average local
time sharing system. Contributing to this problem is the sluggish
response of the server Hosts in adjusting their operating philosophies
and documentation to deal with distant users where assistance cannot
be provided in face to face contact. Further compounding the problem
is that the average user's level of knowledge and familiarity with
the network is dropping as the community expands from the group of
sophisticated and involved Hosts that were initial network participants.

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2)   (cont)

coordinates the installation of the circuits, as well as the inter-
faces with other common carriers when necessary.

Network Measurements Center (NMC)

Network Measurements Center, located at UCLA, has a contract to
perform traffic measurements on the ARPANET. Using a Sigma 7 com-
puter and a Kleinrock simulation model, they stimulate artificial
traffic on the net and conduct time, efficiency and congestion
measurement studies of the network.

Honeywell, Inc.

BBN has in their design of the system hardware specified the
Honeywell 316 computer as the processor for the network nodes. It
was therefore logical to subcontract the maintenance responsibility
to Honeywell as the maintenance organization in the field. Respon-
sibility for calls to Honeywell's technicians rests with BBN/NCC.

Lockheed

BBN has in the development of the HSMIMP specified the Lockheed
SUE minicomputer as the core building block in their design. It
is probable that Lockheed will only serve as a supplier of parts
for the HSMIMP implementation and deployment.

2)   (cont)

on the project. They manage most of the day-to-day operation of
the netowrk as well as provide the design, fabrication and installa-
tion of the IMPs and TIPs; develop the IMP and TIP software; design and
fabricate Host interface when requested, or approve design if Host
customer does their own; maintain hardware (via subcontract with
Honeywell) as well as software for IMPs and TIPs; conduct advanced
research to improve network hardware, and IMP-Host and IMP-IMP proto-
cols; provide and operate the Network Control Center (NCC). The
NCC performs two major functions: (1) it monitors the communication
subnetwork (24 hours a day, 7 days per week); diagnoses failures;
calls on Honeywell or the common carriers, as appropriate, to initiate
maintenance; debugs and reloads IMPs and TIPs; and (2) summarizes
and reports network usage, circuits errors and outages, and IMP per-
formance. Network data is derived from status reports received from
each IMP on the network by the NCC computer. Although the collection
of data has been automated, the analysis of the data has been manual
until very recently. The data is now semi-automatically summarized
monthly for several reports.

Network Analysis Corporation (NAC)

NAC has a contract to design, optimize and recommend to ARPA the
network configuration (topology) for minimum-cost, given the
capacity and reliability specified by ARPA. Whenever a new node
is planned for the network, a new configuration is generated. Based
on these results, the communication lines may or may not be re-
routed. With ARPA funds, NAC developed a computer program (which
changes rapidly) to aid in this network topology planning. NAC
has an average of 4 people working on this project. Along with
BBN, NAC has a very important role in the planning and engineering
of the ARPANET.

Stanford Research Institute (SRI)

SRI has a contract to operate a Network Information Center (NIC)
which is based on an on-line computer program to provide on-line
and hard-copy documentation for network users. Examples of doc-
umentation are announcements of resources available at each Host
site, network protocols and dissemination of working papers for
the members of the Network Working Group.

Defense Commercial Communications Office (DECCO)

DECCO received orders from ARPA for communication services and
procures these from common carriers. They deal with AT&T who
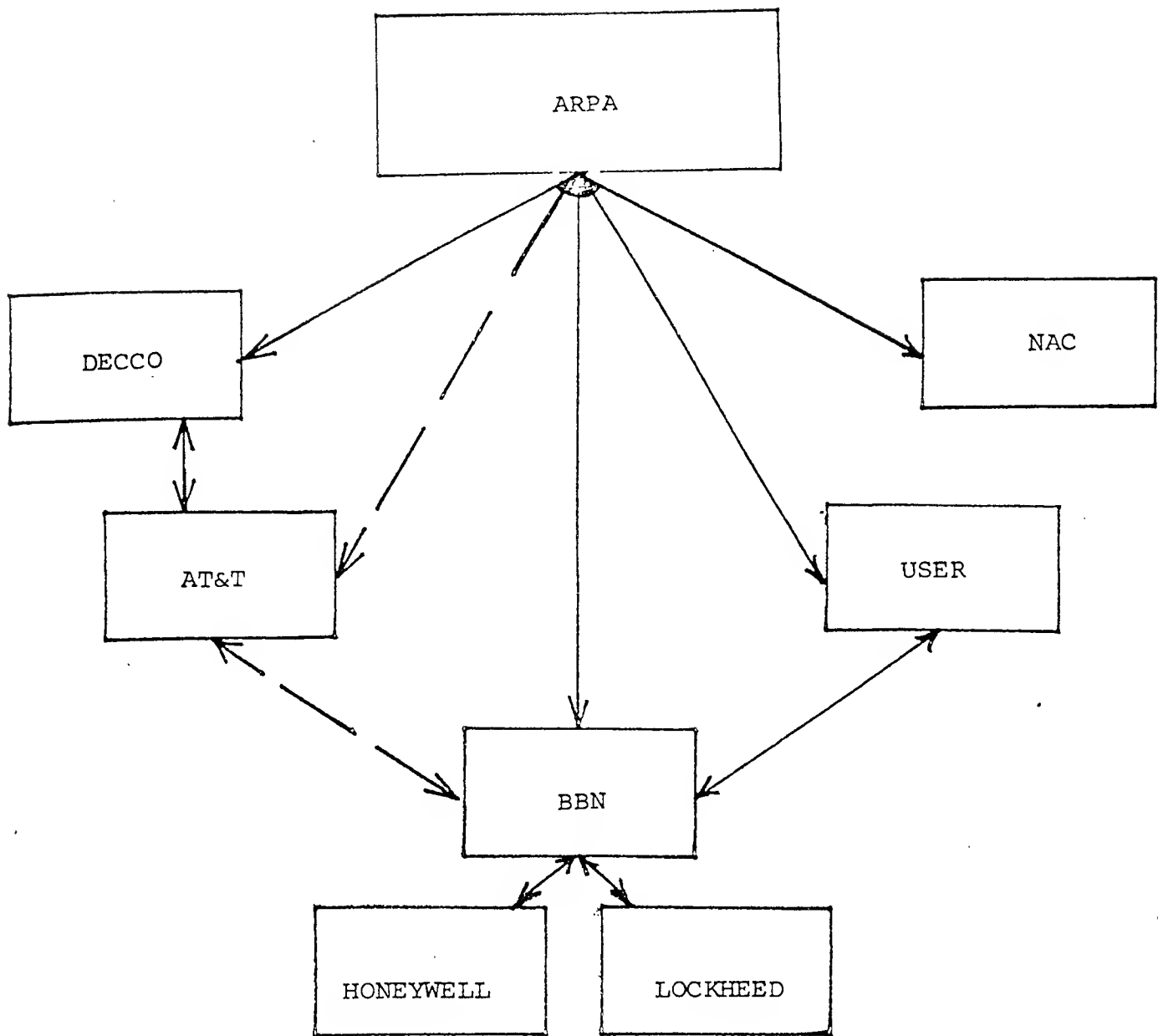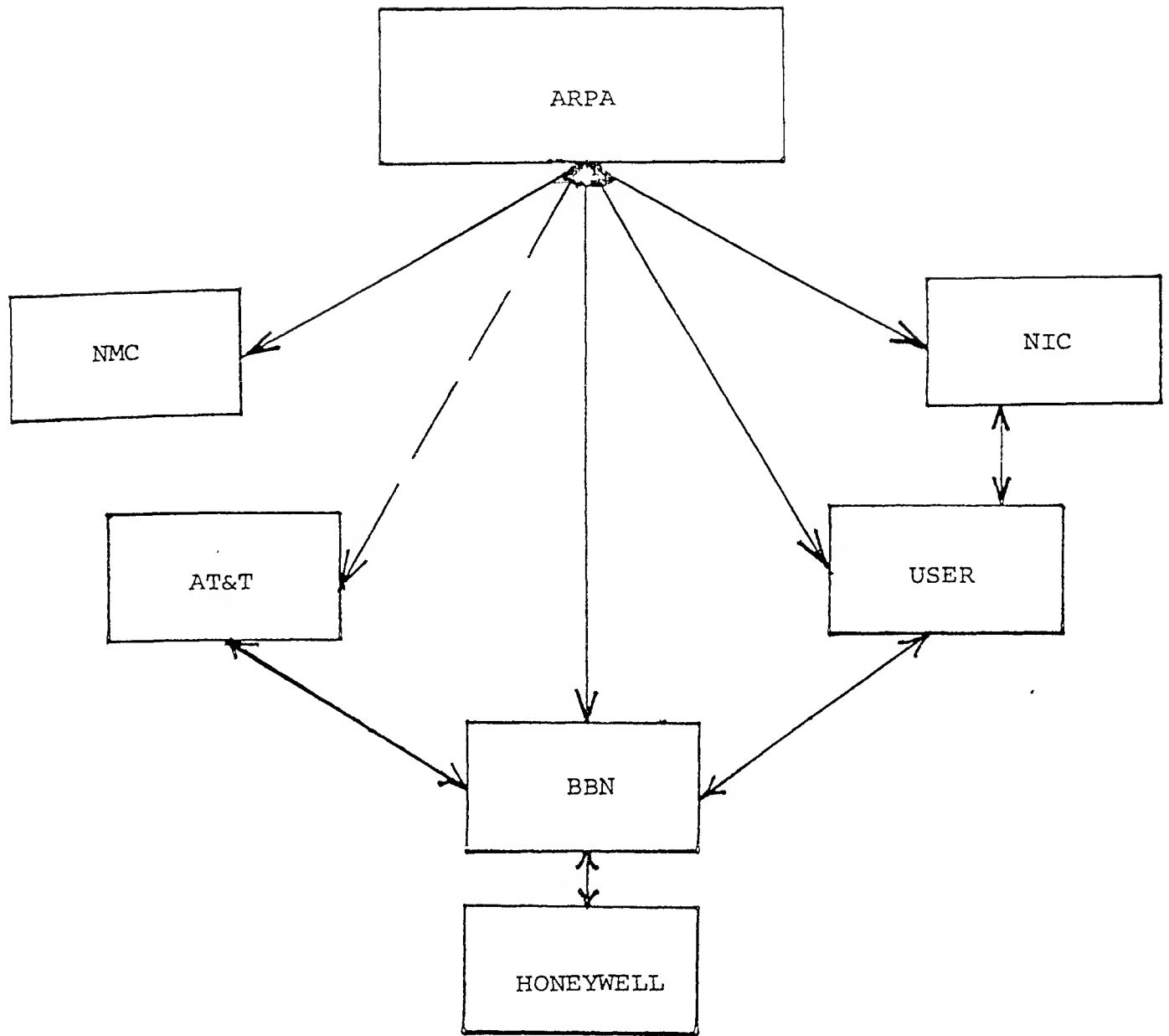
FIGURE 2

FIGURE 1

2)   Network Description

A description of the physical aspects of the ARPANET are readily
available from the literature, and we will only attempt to describe
the operational, organizational and functional configuration of the
existing management structure of the network.

There are three distinct areas of management in the ARPANET:
1) Management of the Host computer systems at each node; 2) Manage-
ment of the daily operations of the communications subnet; and
3) Management of the future development and expansion of the
communications subnet.

The management and administration of the Host computers resides
with the system owner as most are research facilities, and engaged
in numerous activities other than network participation. Preser-
vation of this autonomy was of primary consideration in the net-
work design philosophy.

The network sponsor, ARPA maintains the overall management of the
network. Various aspects of this management responsibility have
been delegated through contracts to perform tasks with regard to
design, fabrication and daily operation of the communications sub-
net.

The organizational and functional relationships between ARPA and
other groups in the daily operation of the ARPANET are portrayed
in figure 1, while ARPA's management of the future development
of the network is shown in figure 2.

Advanced Research Projects Agency (ARPA)

ARPA handles initial contacts with prospective users; treats all
policy and cost matters; negotiates formal agreements with new
users; interacts with the NAC, common carriers, and DECCO to order
new or changed communications services; orders IMPs/TIPs from
BBN; brings new/prospective users and members of the NFG together;
monitors activities of the NWG; generally, functions as the
central management for the network.

Bolt Beranek and Newman, Inc. (BBN)

BBN, on a CPFF contract, is the principal contractor for the
communication subnetwork. BBN has a group of about 25 people now

1)   (cont)

communications at somewhat less than a fourth of the computing
costs of the systems connected to the net.

The insights provided in the above allow us to now return to the
initial statement of ARPANET community purpose and some of its
implications, assuming that a transparent communications service
is available.

Resource availability implies that any program should be able to
call on the resources of other computers in the community with
an ease and reliability and response comparable to calling on one
of its own subroutines. This concept immediately implies the
practicability of distributed access to distributed data bases and
use in data management or data retrieval systems. The impact of
this on the general data processing community may well engender a
radical change in philosophy to take advantage of these capabilities.
For not only can the remote data base be accessed as if it were
local, but the network user can program his own computer to collect
data from several locations for comparison, merging and further
analysis.

The global concepts involved in our initial statement provide a
much more powerful and sophisticated tool in allowing the systems
programmer to call several powerful computers to simultaneously
work on a single problem. We can now begin to visualize the vast
potential of the ARPANET community.

The future becomes very exciting if we consider the network as we
know it today as only the forerunner of future networks. Most of
the information carried by the U. S. Mail today is amenable to
electronic transmission techniques so within twenty years mail may
be relegated to a minor role while most information will be de-
livered via something quite like the ARPANET.

In this future, the corporate executive would have a single console
at his desk, connected into the company computer, which in turn is
a member of the network community. He would be able to request on
his console a wide variety of services from exchange quotations to
his own data management system to a scientific modeling and sim-
ulation service.

1) Purpose of the Network

The basic purpose of the ARPANET community is to provide an environ-
ment in which the resources available to one member are equally
available to other members of the community without degradation or
regard to location. This basic purpose is so global a concept that
it deserves considerable amplification, however we will initially
address the purpose of the ARPANET communication subnetwork.

The subnetwork has been built to provide a transparent communica-
tions medium for the interconnection of a set of interactive
heterogeneous computer installations. The implications of this
simple statement of purpose are not readily apparent, and to under-
stand we must examine the premises of reliability, responsiveness,
capacity and cost on which it is based.

Reliability in a computer community is always compared with the
characteristics of the computer itself. The network design recog-
nized this fact and insured this reliability by providing at least
two transmission paths between any two nodes, and by giving re-
transmission of messages until received error free.

Interactive resource sharing requires a communications responsiveness
within the human short-term memory span, and interactive graphics
use requires rapid reaction to interrupts plus the ability to dis-
play about 20 kilobits of data within one second. The design goal
to satisfy such stringent response requirements was the ability to
transmit a 1,000 bits of data in 0.5 seconds between any pair of
nodes.

The capacity of the communications medium becomes an important con-
sideration when one realizes that with 40 network computers, each
with its dozens of time shared users, there could be, at peak hours,
one or more conversations between all 780 pairs of computers. Net-
work capacity is defined as the throughput rate at which satura-
tion or lowered response occurs, and is dependent on carrier band-
width, topology, traffic distribution between pairs of nodes and
the average message size. The capacity necessary to maintain a
transparent communications medium was incorporated into the net-
work by the flexibility to add transmission lines as needed.

Last but not least in the design premises, is that of cost. Prior
to the implementation of the ARPANET, each computer center was
forced to recreate all of the software and data files it wished to
use, which can be very costly. The ARPANET alleviates this problem
and its value to a user is directly proportional to the number of
other workers on the net who are creating potentially useful re-
sources. The design goal of the ARPANET was to provide

I. Introduction

This report presents the findings, conclusions and recommenda-
tions as a result of an eight week study of the ARPANET covering
the existing operations, development, and administrative
functions of the networks communications subsystems.

The study was undertaken as a result of the networks rapidly
growing popularity and changing character. While retaining
some character of a research and development project with
technological advances still to be implemented and evaluated,
it is simultaneously and rapidly assuming the character of a
highly advanced efficient operational resource sharing net-
work within the DOD research community. This changing character
brings with it a new set of obligations and problems which
must be recognized and dealt with effectively in order to
satisfy the goals of the two "half worlds".

The content of the report is not intended to be critical of
any individuals or groups efforts as they presently exist,
but rather to point out areas requiring changes, different
approaches, and new effort in order to effectively continue
the R&D effort while satisfying the new operational network
demands. Another important consideration is the posture and
character required of the network to be ultimately attractive
to commercial interests.

The study consisted of discussions, demonstrations, and observa-
tions at the headquarters and operating sites of all network
contractors and agencies required to sustain daily operations.
The following organizations were visited:

Advanced Research Projects Agency, Arlington, Virginia
Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts
Network Analysis Corporation, Glen Cove, New York
MITRE Corporation, McLean, Virginia
American Telephone & Telegraph, Washington, D. C.
Massachusetts Institute of Technology, Cambridge, Massachusetts
Stanford Research Institute, Menlo Park, California
Ames Research Center, NASA, Mountain View, California
Rand Corporation, Santa Monica, California
University of California at Los Angeles, California
Univeristy of California at Santa Barbara, California
Information Sciences Institute, Marina Del Ray, California

A summary of the findings with appropriate recommendations
are presented in Section II.

1

TABLE OF CONTENTS

RFC	Request For Comments
RFNM	Ready For Next Message
HOST	Computers Interfaced To IMPS And TIPS
TNLS	Telnet On Line System
NODE	IMP/TIP Location
IMP	Interface Message Processor
TIP	Terminal Interface Message Processor
AT&T	American Telephone And Telegraph
TENEX	PDP-10 Operating System As Modified By BBN
HSMIMP	High Speed Modular IMP

GLOSSARY

ARPA	Advanced Research Projects Agency
DECCO	Defense Commercial Communications Office
DOD	Department of Defense
BBN	Bolt Beranek and Newman, Inc.
NAC	Network Analysis Corporation
SRI	Stanford Research Institute
NIC	Network Information Center (SRI)
ISI	Information Sciences Institute
NCC	Network Control Center (BBN)
NFG	Network Facilitators Group
UCLA	University of California Los Angeles
UCSB	University of California Santa Barbara
MULTICS	Computer Language Developed at MIT
MIT	Massachusetts Institute of Technology
NMC	Network Measurements Center (UCLA)
NWG	Network Working Group
RJE	Remote Job Entry
OLS	On Line Service
MTU	Magnetic Tape Unit
IMPSYS	IMP Network Program
IMPLOAD	IMP Automatic Loading Subroutine
RJS	Remote Job Service
R&D	Research and Development
NLS	On Line System

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